Downloaded from orbit.dtu.dk on: May 05, 2023

DTU Library

DNAPL source zone architecture in clay till and limestone bedrock

Characterization by innovative and current site investigation techniques

Broholm, Mette Martina; Janniche, Gry Sander; Fjordbøge, Annika Sidelmann; Jørgensen, Torben; Damgaard, Jesper; Martinez, Kerim; Grosen, Bernt; Wealthall, Gary; Christensen, Anders G.; Kerrn-Jespersen, Henriette

Publication date:
2013

Document Version
Publisher's PDF, also known as Version of record

Link back to DTU Orbit

Citation (APA):
Broholm, M. M. (Author), Janniche, G. S. (Author), Fjordbøge, A. S. (Author), Jørgensen, T. (Author), Damgaard, J. (Author), Martinez, K. (Author), Grosen, B. (Author), Wealthall, G. (Author), Christensen, A. G. (Author), & Kerrn-Jespersen, H. (Author). (2013). DNAPL source zone architecture in clay till and limestone bedrock: Characterization by innovative and current site investigation techniques. Sound/Visual production (digital), DTU Environment. http://www.conference.ifas.ufl.edu/gq13/Presentations/2-Tuesday/am/yes/1000_Broholm.pdf

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

DNAPL source zone architecture in clay till and limestone bedrock

Characterization by innovative and current site investigation techniques

Mette M. Broholm[1], Gry S. Janniche[1], Annika S. Fjordbøge[1], Torben Jørgensen[2], Jesper Damgaard[2], Kerim Martinez[2], Bernt Grosen[2], Gary Wealthall[3], Anders G. Christensen[4], Henriette Kerrn-Jespersen[5]

[1]DTU Environment, [2]COWI, [3]GeoSyntech, [4]NIRAS, [5]Capitol Region of Denmark

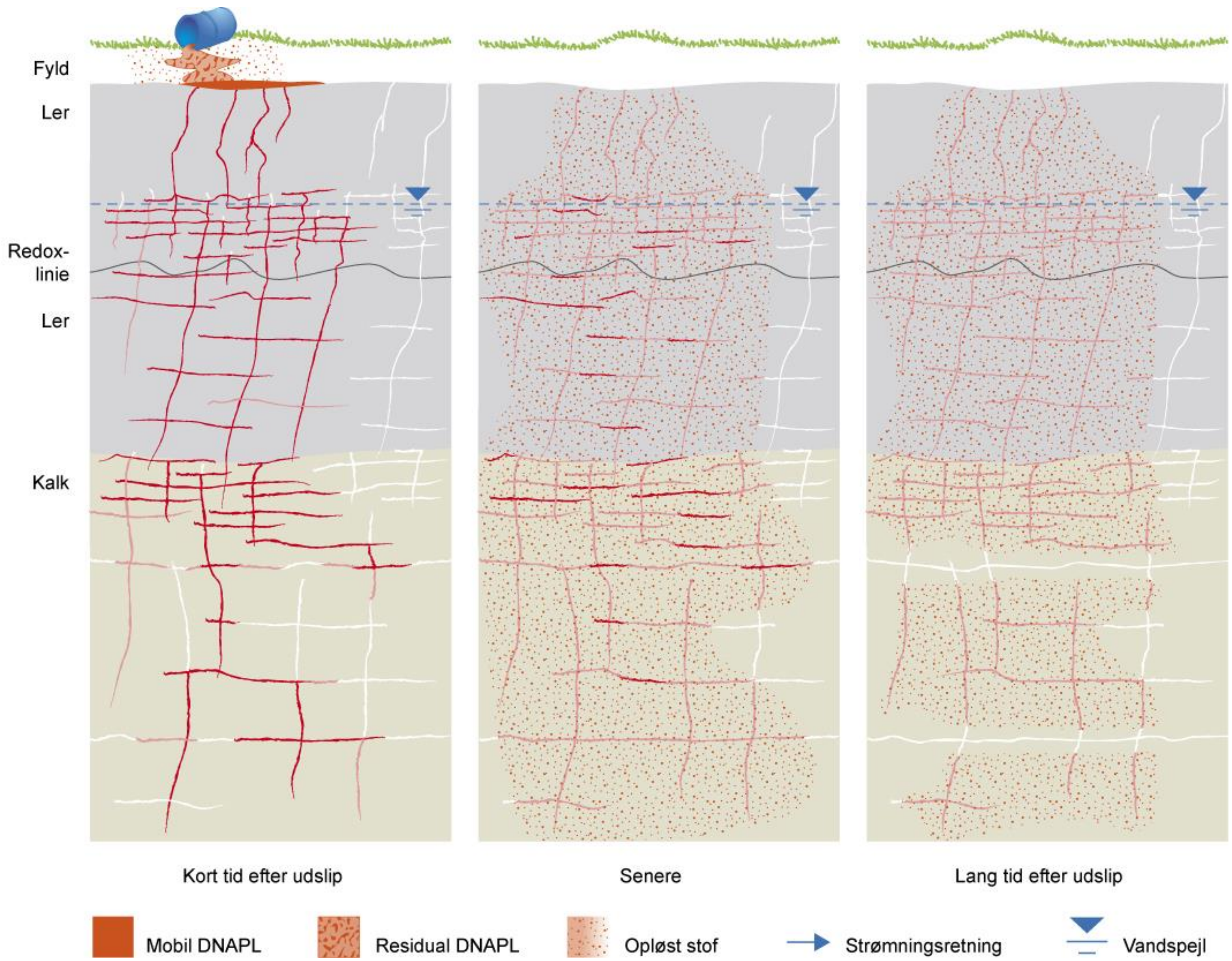
Background and scope

- Characterization of dense non-aqueous phase liquid (DNAPL) source zone architecture is essential to:
  - Develop accurate site specific conceptual models
  - Delineate and quantify contaminant mass
  - Perform risk assessment and
  - Select and design remediation alternatives

- DNAPL architecture not well understood for
  - Clayey till
    - Fractured low permeability media
  - Limestone bedrock
    - Fractured variable permeability media

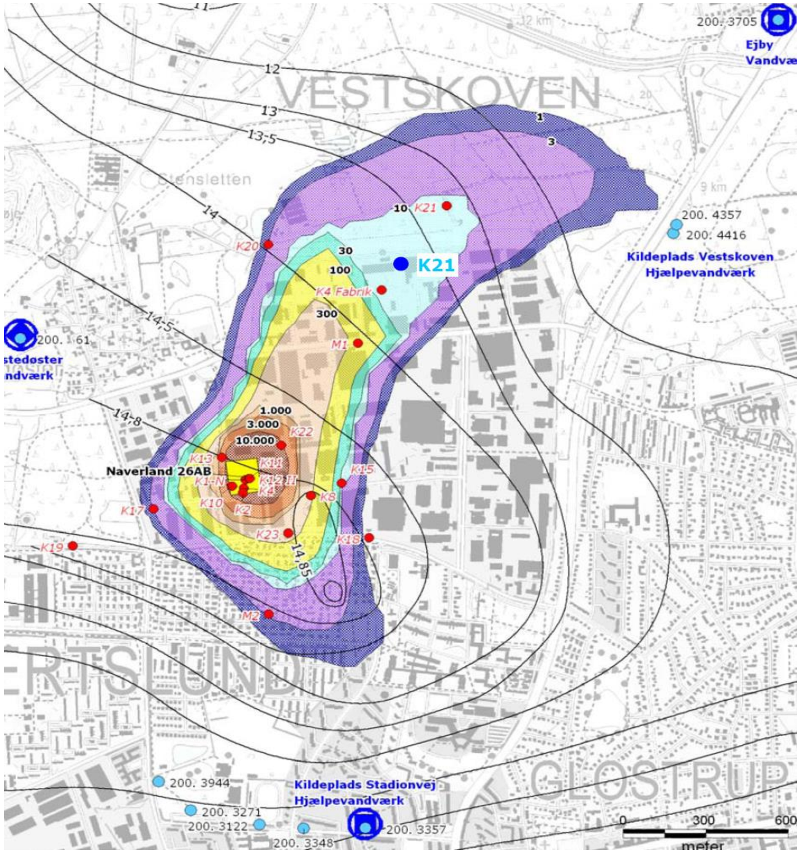
- Scope
  - Innovative techniques evaluation
  - Improved conceptual understanding of DNAPL source zone architecture in clayey till and limestone bedrock

DNAPL conceptual model for clayey till and limestone bedrock - general



Site and approach

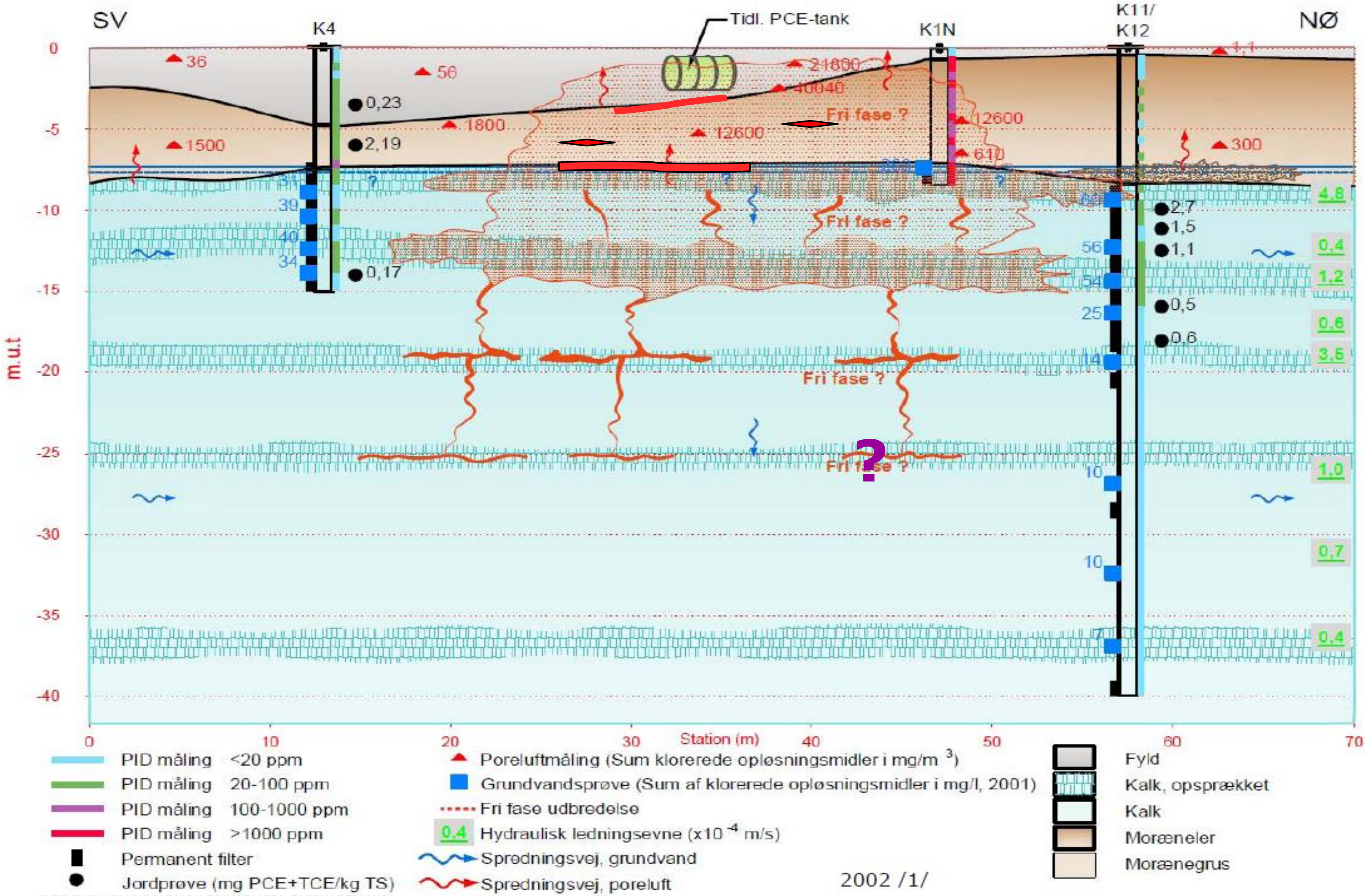
- Site
  - Distribution facility at Naverland, Albertslund, Denmark
  - Chlorinated solvents handled: PCE 5.000 t, TCE 1.500 t, TCA 200 t
  - PCE and TCE DNAPL impact
  - Clayey till, fractured
  - Bryozoan limestone bedrock
- Approach
  - Innovative and current investigative techniques
  - Multiple lines of evidence
  - Characterization of hydrogeology
  - Characterization of contamination
    - **DNAPL**
    - Dissolved and sorbed phase



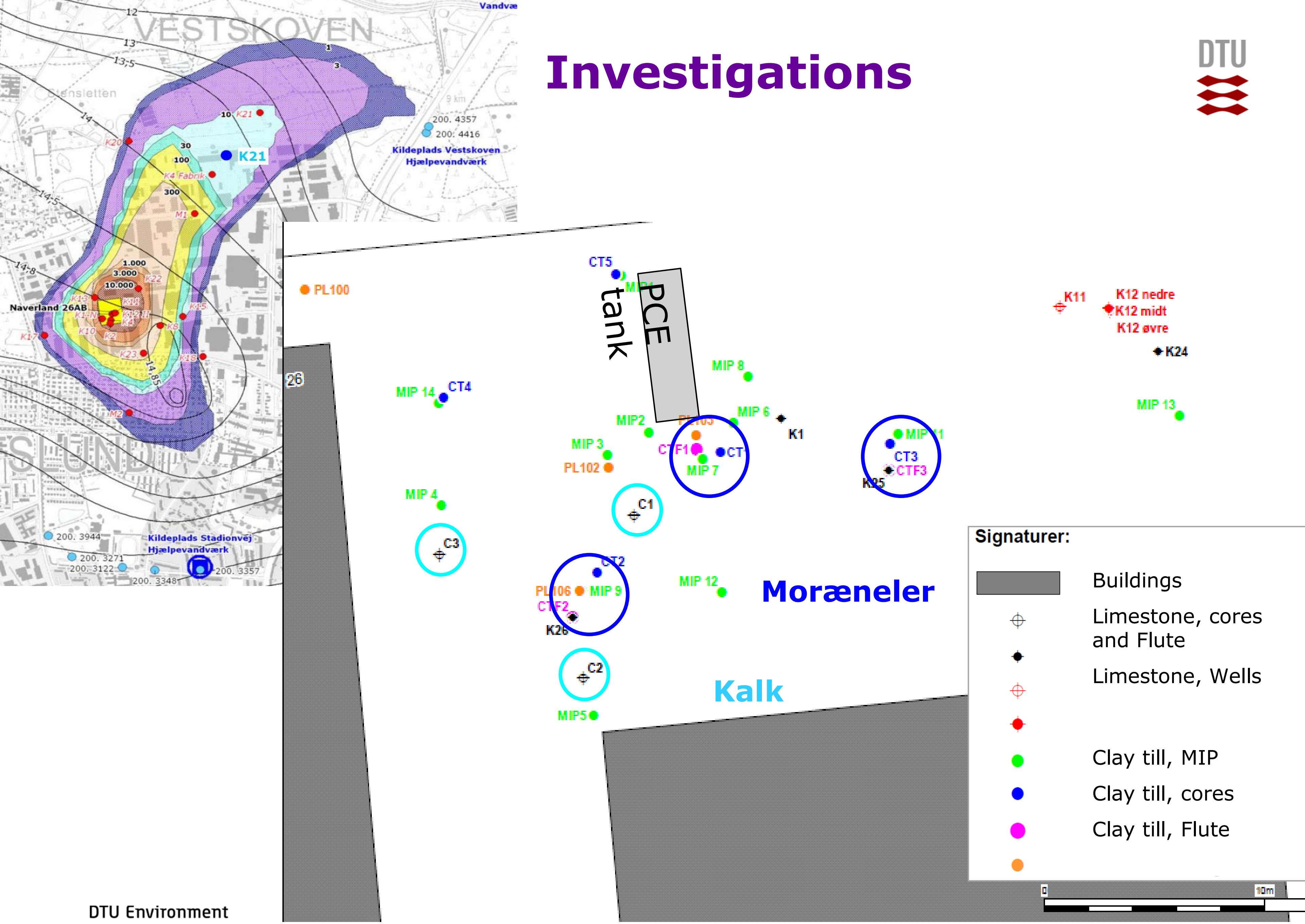
Chlorinated solvent plume, 2008

Naverland. Source zone conceptual model

Remedial pumping



Investigations



Characterization techniques – Clayey till

Surface

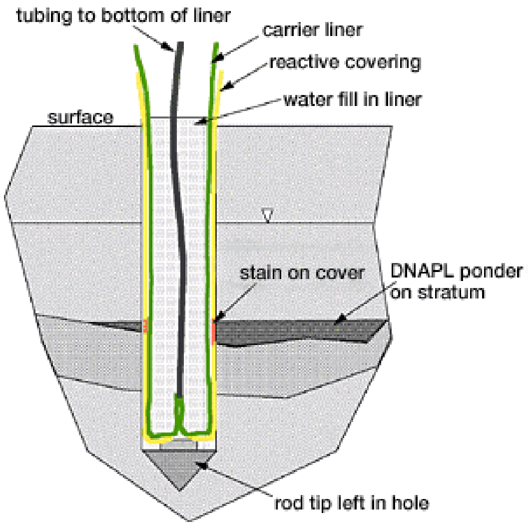
- Georadar and seismic geophysics

Clayey till

- Membrane interface probing (MIP) with FID, ECD, GC-MS
- Coring
  - Discrete subsampling for quantitative analysis
  - PID
  - Sudan(IV) and colorspray
  - Geology
- NAPL and FACT FLUTe
  - Exposure
  - PID
  - Discrete FACT subsampling for analysis
- Liquid sampling
- Radon and soil gas sampling

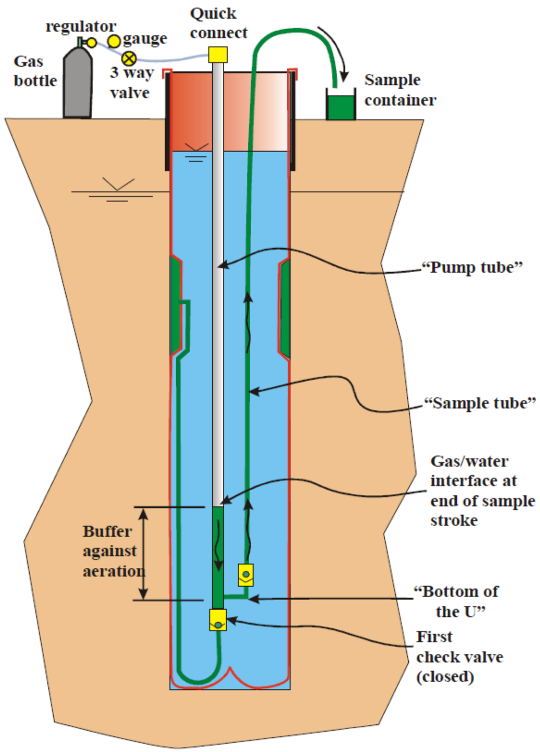
Red = DNAPL

Green = no DNAPL

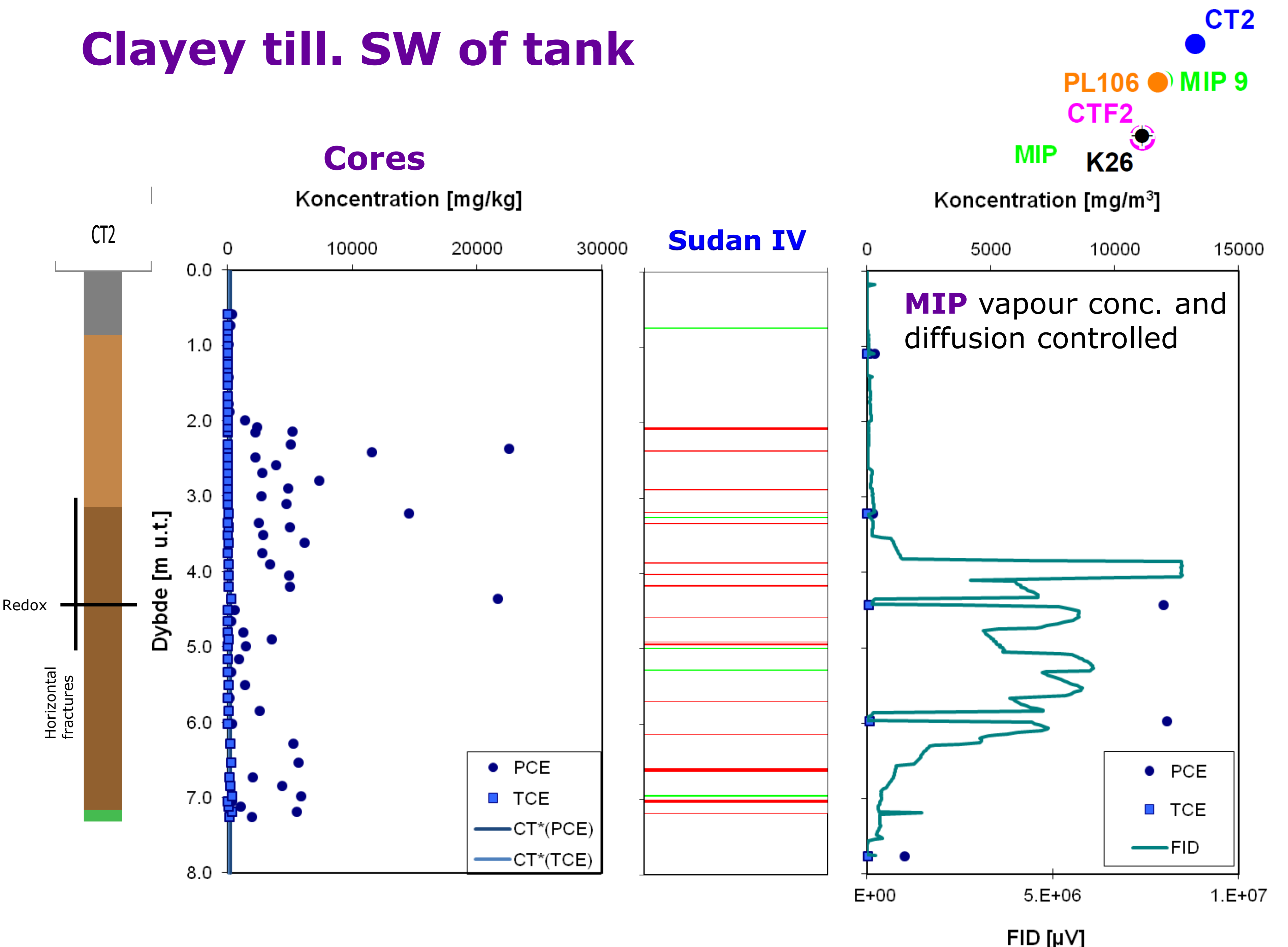


Characterization techniques Limestone Bedrock

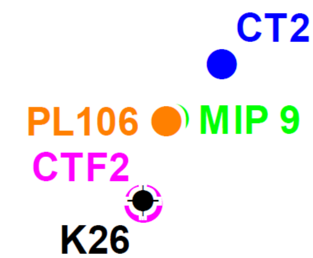
- Coring
  - Discrete subsampling for quantitative analysis
  - PID
  - Sudan(IV)
  - geology
- NAPL and FACT FLUTe
  - Exposure
  - PID
  - Discrete FACT subsampling for analysis
- FLUTe transmisivity tests
- Water Flute
  - Discrete groundwater sampling for quantitative analysis
  - Water potentials



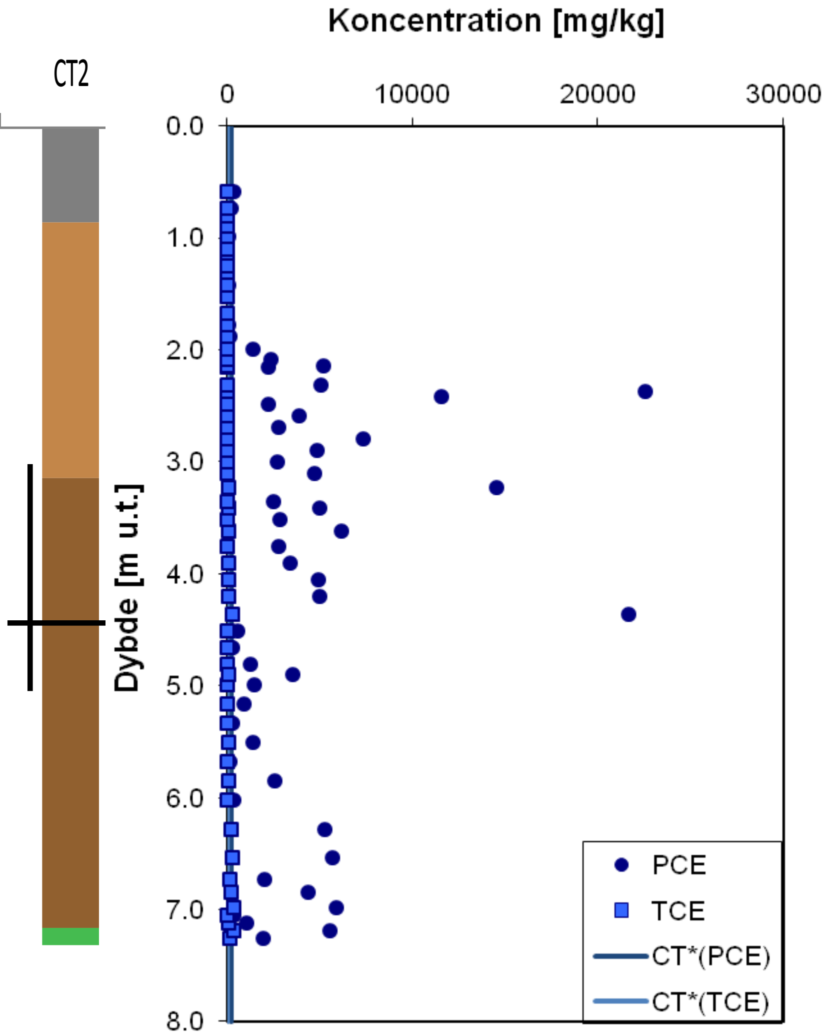
Clayey till. SW of tank



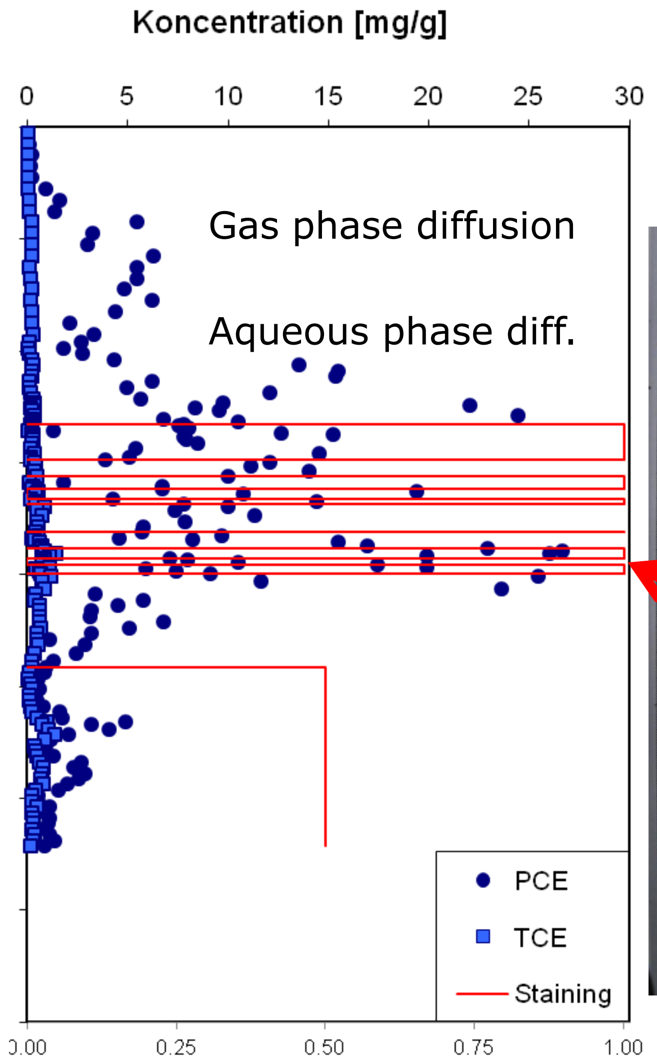
Clayey till. SW of tank

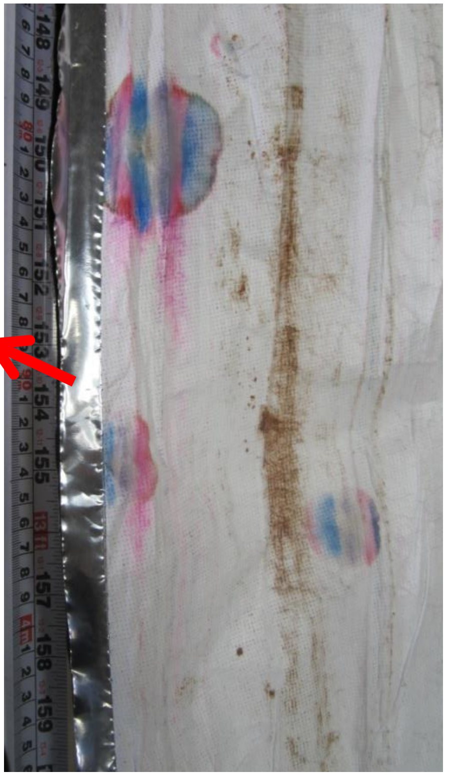


Cores



FACT NAPL





Clayey Till

- **Characterization techniques**

- Geophysics for clayey till and chalk surface mapping

- MIP, PID, FACT for screening
- Sudan(IV), NAPL FLUTe, core conc. for NAPL documentation
- Core conc. for quantification

- Colorspray, radon, poreair conc. not usefull

- Generally good correlation between MIP, Sudan(IV), PID, NAPL FLUTe, FACT FLUTe, and core concentrations
  - considering distance

- **Combination of techniques recommended**

Clayey Till

- **Conceptual model development**

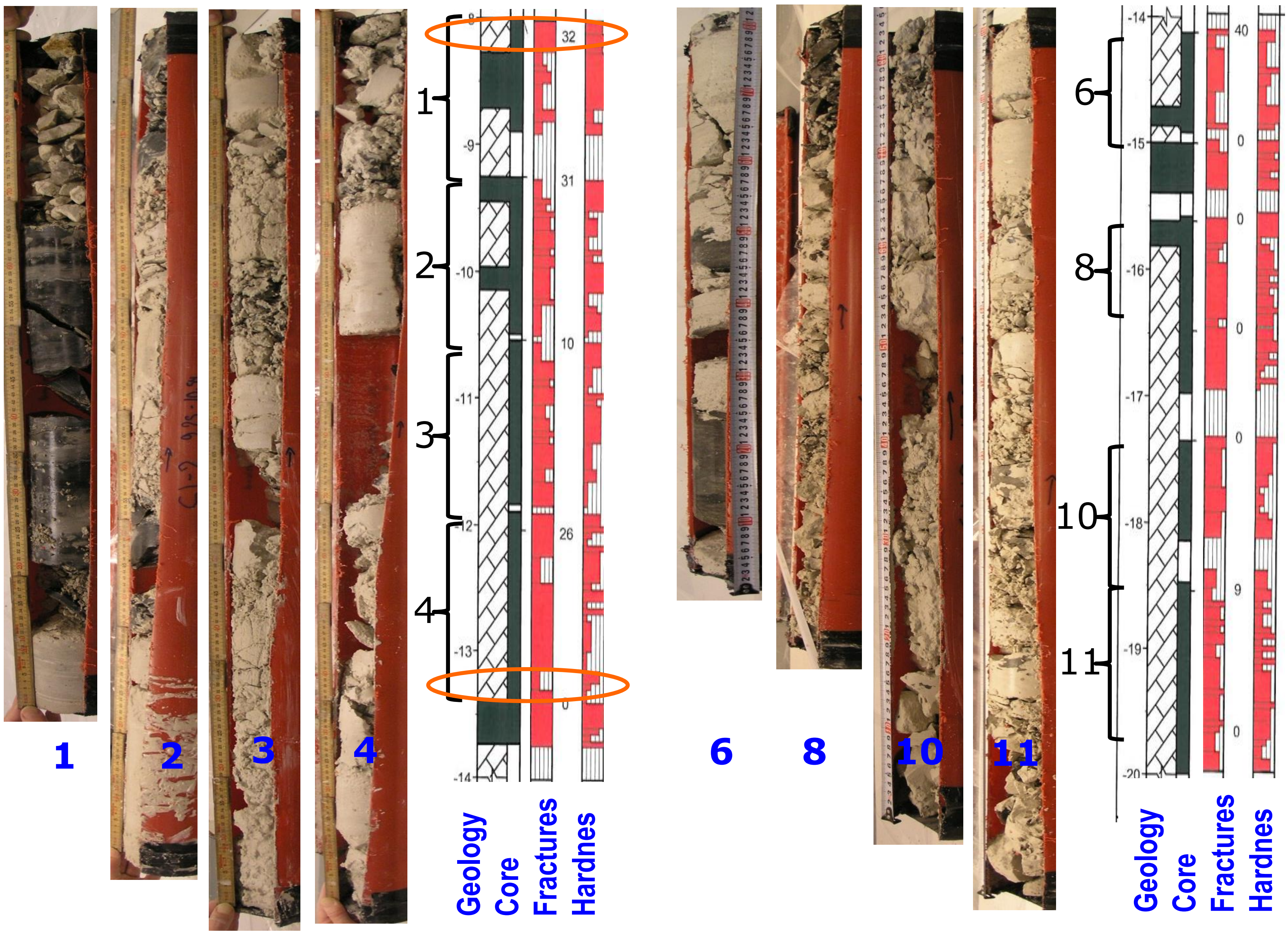
- Apparent residual saturation (porous media): 1-16%
- Fracture V 0.1-1%: Mobile DNAPL

- Suggest pooled/connected phase in fractures
  - where NAPL FLUTe stained

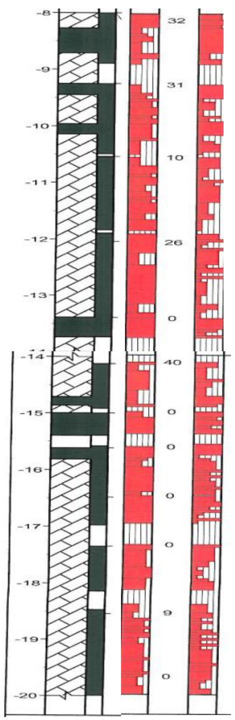
- DNAPL observed
  - at clayey till surface
  - In fractures in zone above redox change (4.5 m) with closely spaced horizontal fractures (3-5 m)
  - In fractures below redox change
  - Gravel below clayey till

- Most and deepest DNAPL SW of tank/release area
  - Clayey till surface and fracture-dip direction

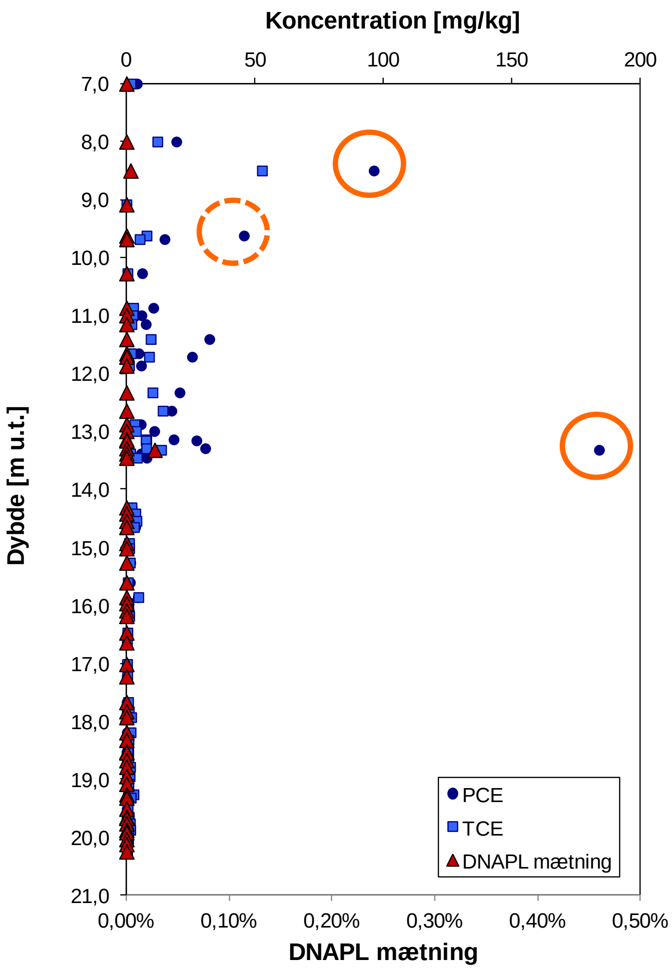
Limestone bedrock C1



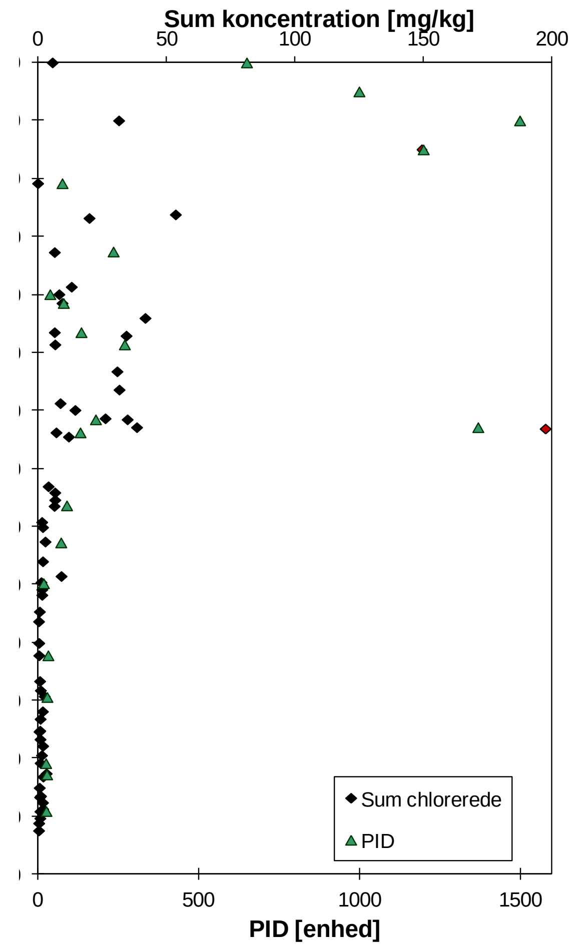
Limestone bedrock, cores



Kernekoncentrationer



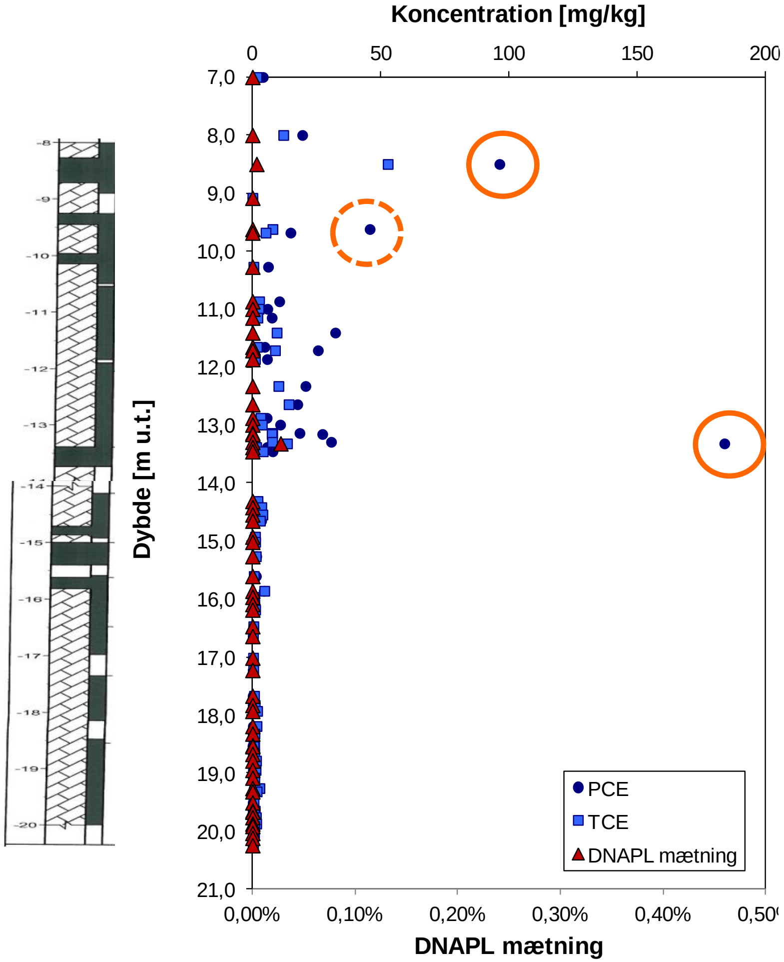
PID og sum af chlorerede



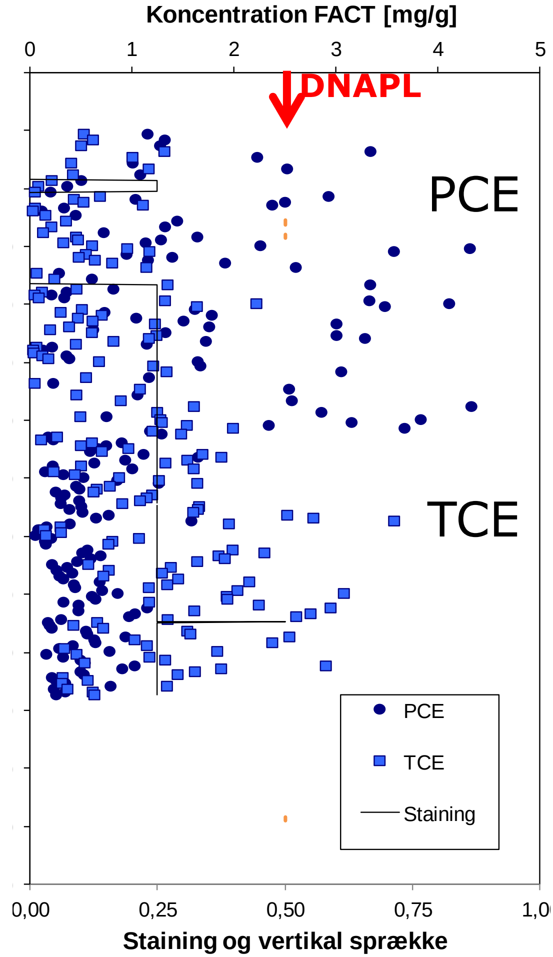
PCE residual

Limestone bedrock

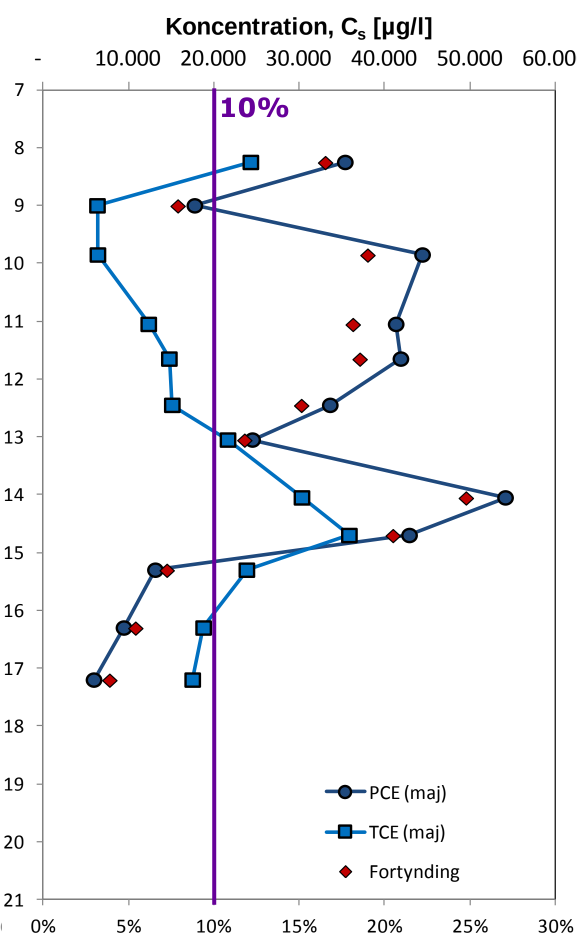
Cores



FACT NAPL FLUTe



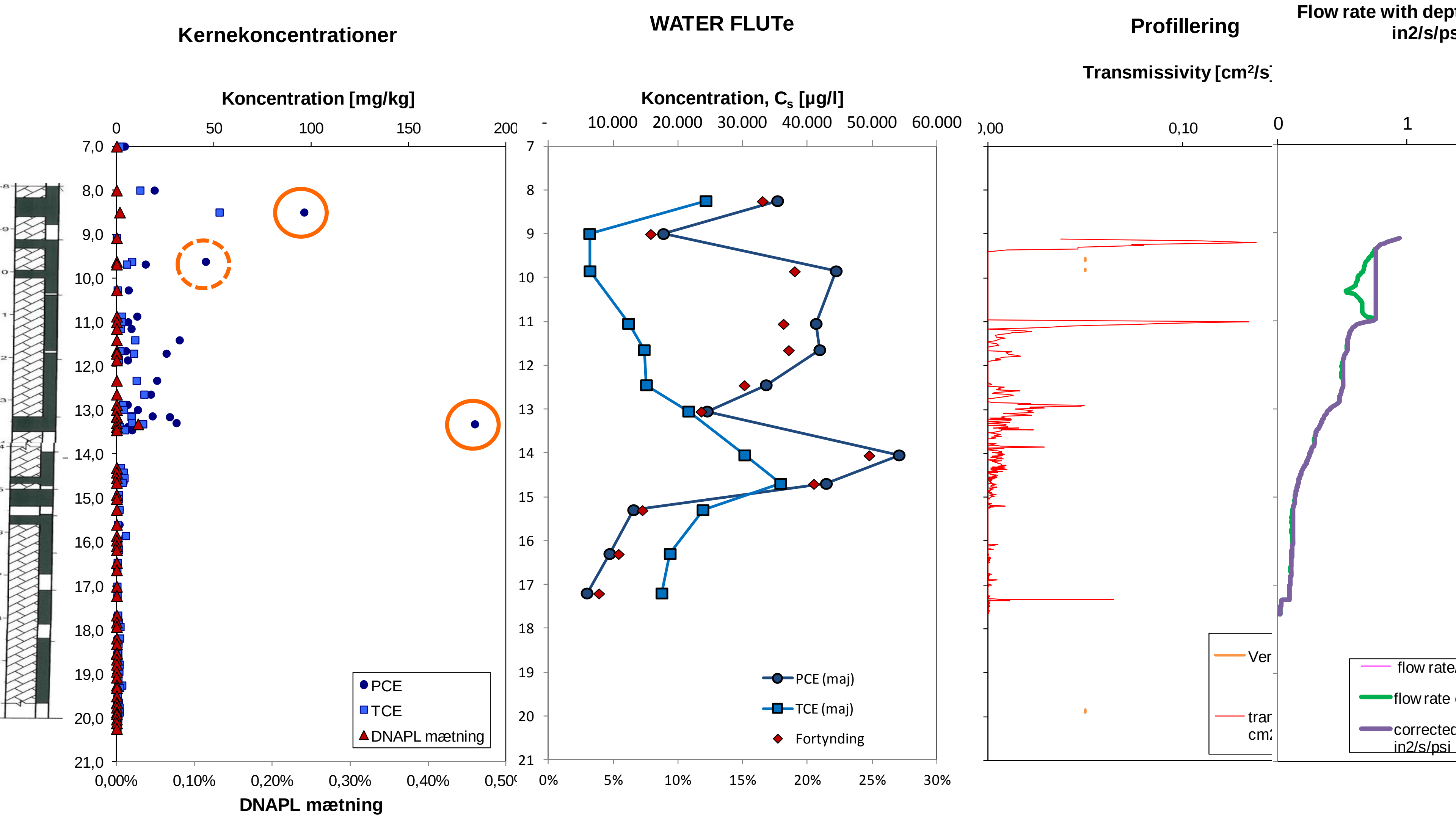
WATER FLUTe



FACT uptake solubility and diffusion controlled

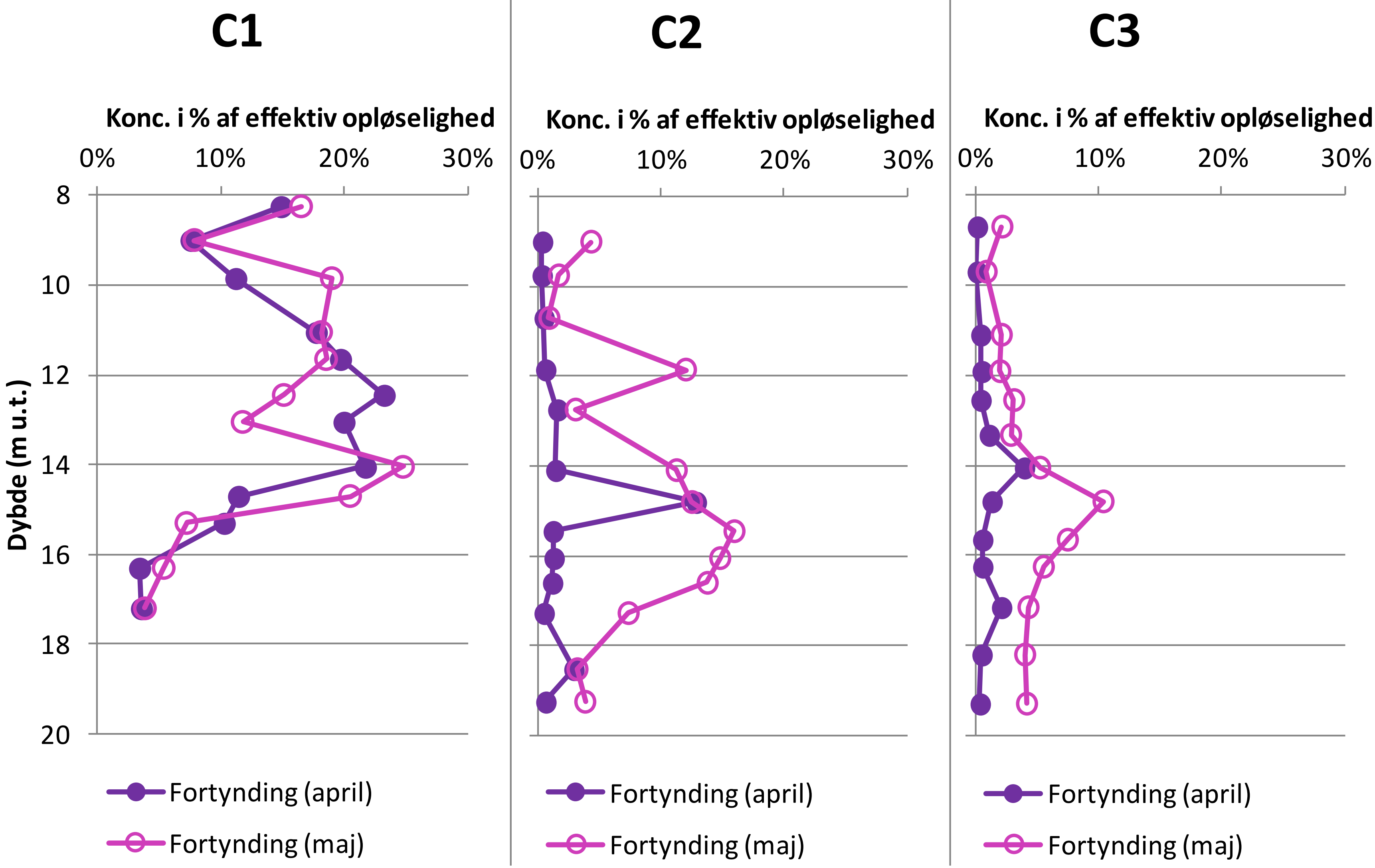
Aqueous conc. solubility controlled

Limestone bedrock



High transmissivity. Potential initial DNAPL path.
But higher dissolution and potential depletion

Rebound when remedial pumping off



- C1: constant, > 10% S, DNAPL controlled
- C2+3: rebound to > 10% S, backdiffusion contr.

Limestone bedrock

- **Characterization techniques**
- Core loss and potential DNAPL loss during coring
  - (PID)
  - (Sudan(IV), NAPL FLUTe, core conc. f NAPL documentation?)
  - (Core conc. for quantification?)
  - Colorspray, radon not usefull
- FACT for screening
- Water samples for screening
- Generally good correlation between, FACT FLUTe and water sample conc.
- **Combination of techniques recommended**
- Better coring technique needed
- FACT testing needed
- Screening techniques needed

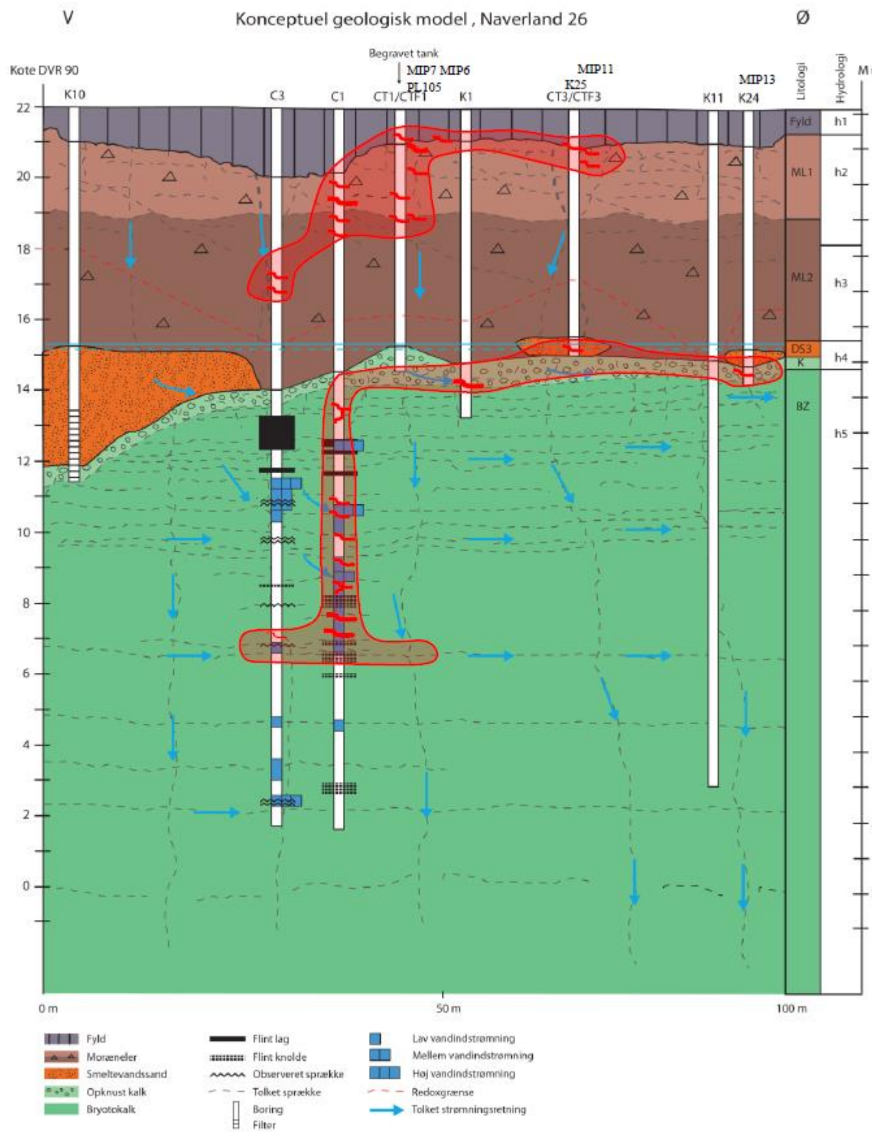
Limestone bedrock

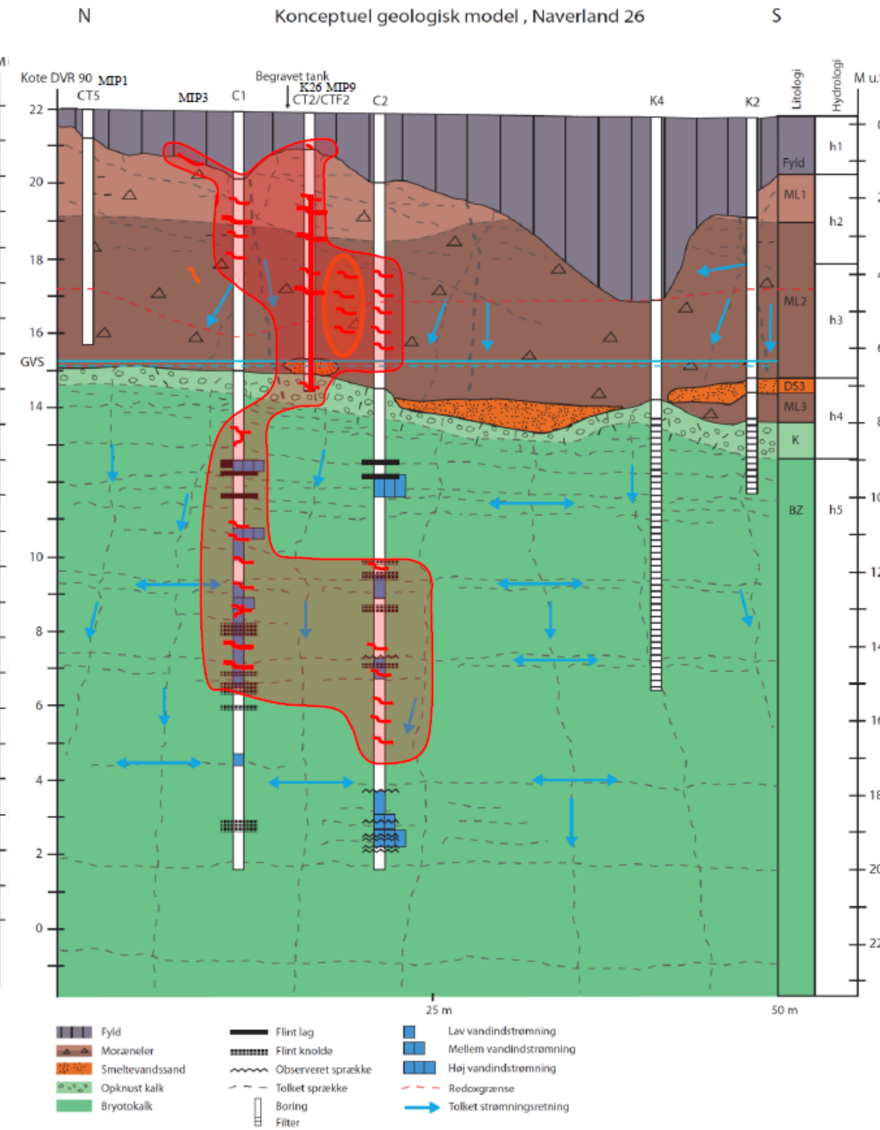
- **Conceptual model development**

- Apparent residual sat.: none-0.1%
- Fracture V 1%?: No or residual NAPL
- Very low – loss during coring?

- DNAPL indicated
  - Documented in 2 core samples in chalk overlying flint beds
  - FACT and water samples strongly indicate DNAPL pressence in: C1 8-15 m bs and C2 15 m bs
  - Rebound indicate very high matrix conc. (former and possibly current DNAPL) in greater parts of the limestone bedrock

Conceptual model





Conclusion. Characterization

- Combined use of techniques gave good insight in source zone architecture in clayey till
  - MIP and PID were succesfull as screening tools
  - Sudan(IV) for DNAPL
  - NAPL FLUTe for mobile DNAPL
  - Cores for geology, PID and Sudan(IV)
  - Core subsample quantitative analysis – needed for quantification
- Characterization of DNAPL architecture in limestone bedrock is a challenge
  - Water samples for screening
  - FACT FLUTe promissing – needs further testing
  - Cores for geology
  - Cores for quantitative analysis and Sudan(IV) a challenge
  - Watersampling under 2 conditions – improved understanding
- Other potential methods
  - Dye-LIF, Borehole logs, Cross-borehole geophysics

Conclusion. DNAPL

- DNAPL at clayey till interface and in fractures
- Mobile DNAPL still present in fractures in clayey till
- DNAPL in gravel/crushed chalk zone
- DNAPL residual strongly indicated in fractures in limestone bedrock to 15 m bgs

- **Complex DNAPL sourse zone architecture**

Acknowledgements

- The presented results were financed by the Capitol Region of Denmark
- Student and technicians at DTU Environment, COWI, NIRAS and FLUTe assisted with field and laboratory work

Reference: Janniche et al. 2012, www.sara.env.dtu.dk